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RECENT CROSS-COUNTRY STUDIES OF GROWTH: A SURVEY*

RODRIGO FUENTES**
Departamento de Economía
Universidad de Chile

Abstract:

Over the last decade there has been a renewed interest for understanding the phenomenon of growth both at theoretical and empirical levels. At the time of this paper there is an enormous volume of literature that uses cross-country regressions to link convergence in per capita output with economic policies, human capital accumulation, externalities and increasing returns. This paper analyzes the econometric results of recent cross-country studies of growth. After a brief review of this empirical literature, a discussion on testing the theory of growth, interpretation of the coefficients, robustness, error in variables, and measurement of human capital is provided. The main conclusion is that this type of studies provide useful sets of correlations between variables that tend to affect growth and long-run growth rate of per capita GDP. But, these correlations are not a test of the theory and furthermore there is a lack of alternative hypothesis. Another main disappointment is that these coefficients are not constant across all the observations, and therefore, structural equations for these coefficients should be considered. Country-case type of studies and the analysis of other proxies for human capital are suggested as further researches.

Over the last decade there has been a renewed interest for understanding the phenomenon of growth at both theoretical and empirical levels. At the former level researchers have worked with certain stylized facts that the traditional neoclassical theory of growth apparently has left unexplained. Specifically, these new models are called endogenous growth models since they reproduce a theoretical structure where an

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economy can experience sustained endogenous growth. This is the main difference with Solow's model, where the growth in per capita income was given by the exogenous technological growth rate. On the empirical side researchers have contrasted the neoclassical and the endogenous growth models with cross-country data.

The main goal of this paper is precisely to analyze the methodology of these cross-country studies. Given that the number of studies is increasing at an increasing rate, I think it is useful to summarize and analyze the methodology used. Some of the issues to be addressed here are related with the connection between theory and empirical evidence, what conclusions can be derived from cross-country studies, interpretations of the coefficients estimated, the importance of measurement errors in the variables, and robustness of the results. Also, alternative ways of measuring human capital will be discussed.

To make this paper self contained, in the next section I will discuss briefly the implications from the different group of models without entering into the details of their mathematical formulation and in the detail of each paper[1]. In the second part I will review some of the most important empirical studies to proceed in the following two sections with a discussion of econometric issues and variable construction. Section five display some concluding remarks and further research directions.

I. Models of Growth: A Brief Survey

The benchmark for the theoretical modelling of growth was provided by Solow (1956) and later by the independent works of Cass (1965) and Koopmans (1965). This set of models, called the neoclassical growth theory, derives a long run equilibrium known as steady state with growth of neither per-capita income nor per-capita capital. In other words, income and capital grow at the exogenous rate of population growth.

The observed growth in per-capita income is explained by the exogenous technological change. In this model the saving rate and government policies have only a level effect but no growth effect in the long run.

One of the main implications of this model, that raises a long controversy in both empirical and theoretical arenas, is that per-capita income will converge across countries after controlling for saving rates and growth rate of population. A key assumption is that the technology is given and it is the same for all countries as well as the rate of technological progress. If one wants to think in a more realistic model, one which includes international trade and capital flight the speed of convergence will be even higher since poorer countries should have a higher marginal productivity of capital, which will be an incentive for capital inflows. This movement will stop if the interest rate is equalized across countries.

A more formal and simple way to express the above formulation is to use a Cobb-Douglas production function $y = Ak^{\alpha}$, where y and k mean output and capital per worker respectively. A is a technological parameter. The growth rate of this economy is given by equation (1).

$$\hat{y} = \hat{A} + \alpha\hat{k} \tag{1}$$

where, as usual, the "^" means growth rate.

In a steady state capital grows at the same rate of labor force. Therefore the growth rate of per worker output depends only on the exogenous growth rate of technological progress or also called the change in "Solow's Residual" (see Solow (1957)).

The accumulation path of capital per worker is given by

$$\dot{k} = sf(k) - nk \tag{2}$$

where the dot represent the derivative respect to time and, s, n and f (k) are the saving rate, the growth rate of population and the production function characterized by constant returns to scale, so f (k) is output per worker. The saving rate is assumed to be net of depreciation. In a steady state, the above equation is equal to zero; then the following condition holds

$$y = f(k) = \frac{nk}{s} \tag{3}$$

So, as discussed above, this model implies convergence in labor productivity (or per capita income if the rate of population growth is the same as the growth rate of labor force) after controlling for the saving rate and the growth rate of labor force. Note that in (3) we could solve for capital per worker which would be the same across countries. Using a Cobb-Douglas production function the steady state capital per worker is $k = (s/n)^{1/(1-\alpha)}$.

The starting point for the new models in growth theory is to make the process of growth endogenous. Thus they include human capital as another factor that could be accumulated and introduced it as Harrod-neutral type of technological progress[2]. Another way to make the growth endogenous and sustained is the inclusion of externalities or increasing returns in a production factor called knowledge that could be accumulated through research and development[3]. These two settings, basically, make the change in A, in the above production function, endogenous. They work with constant return to scale in the typical factors capital and labor. But the interpretation of A is an improvement in the quality of labor or A is the aggregate stock of knowledge that produces an externality.

Another line of endogenous growth model is the one that deals with the pure accumulation of production factors[4]. Here the condition to have endogenous sustained growth is that the function of factor accumulation shall exhibit constant return to scale in all the factors that could be accumulated. Taking, for example, Solow's model with only one reproducible factor, the above condition would state that the production function must be asymptotically linear to generate sustained endogenous growth, or in other words the marginal productivity needs to be bounded from below. The same interpretation is not valid with more than one reproducible factor, in the sense that what we need is a balanced growth of all reproducible factor. With constant returns to scale and a balanced growth of the reproducible factors, endogenous sustained growth will be generated[5].

In many of these new growth models countries do not need to converge neither in growth rates nor in levels of per capita output. This feature seems to be confirmed by the stylized facts. Nevertheless, the discussion about convergence originated several empirical cross-countries studies that will be reviewed next. These endogenous growth models have been also used to study the effects of distortions, government spending, product cycle and trade. By now, the discussion is centered on conditional convergence in the sense that countries would converge after controlling for the variables mentioned above. Also in Solow's model nothing affects growth except the exogenous

technological changes, while in this new literature we found theoretical basis for new determinants of economic growth.

II. Review of the Cross-Country Studies

I will organize this section around three main study groups of studies. The first group of papers follows the discussion about the convergence hypothesis. Specifically, they test convergence in a Solow's fashion against conditional convergence, *i. e.*, convergence exist after controlling for human capital, political instability, etc. The second group emphasizes the role of macroeconomic variable (meaning inflation, external debt, money supply shocks, etc.) as determinants of growth. The last group studies the relationship between growth and openness.

As we discussed in the previous section, Solow's (1956) paper originated a large body of literature in both the theoretical and the empirical arenas[6]. Specially it has arisen a controversy, at the empirical level, about the convergence hypothesis outlined in the previous section. This controversy started with Baumol (1986) who showed that there exist convergence in a sample of 16 industrialized countries. Basically his test consisted in a regression of growth since 1870 on 1870 productivity and he found a negative coefficient. The idea is that poorer countries will grow faster since they are far away from the steady state, this is the idea of "catching up".

De Long (1988) criticizes Baumol's methodology arguing that it has two problems: sample selection bias and measurement error in the independent variable. The former critique comes from the fact that the sample includes countries that *ex post* have converged in productivity. In order to have an *ex ante* unbiased sample it would be relevant to ask if the countries, that back in 1870 were likely to converge, actually converged. In other words we cannot choose a sample of economies that *ex post* have converged, but a sample of nations that were rich and well integrated into the world economy, and then analyze if the regression analysis can tell us anything about convergence. Excluding Japan from the sample, because it did not look like an economy with high potential for convergence in 1870, and adding economies like Argentina, Chile, Portugal and Spain that look more likely to converge because they had a much higher per capita income than Japan in 1870, De Long found that there is no evidence of convergence.

De Long also analyzed the measurement error problem and found that allowing for small measurement error (measured as the variance of the error to the variance of the disturbance) the coefficient tends to be zero at the classical level of significance and eventually turns to be positive. He also analyzed the inclusion of a *dummy* variable for democracies and for the dominant religion in the country. According to him the latter seems to be a good proxy for the social capability to assimilate modern technology, since he found that the incidence of protestantism in the society tended to help growth.

Barro (1989), using Summer and Heston (1988) data set for 98 countries, found that there is no correlation between growth in per capita GDP since 1960 and the level of 1960 per capita GDP. But after controlling for several variables initial level of human capital, a proxy of distortions and political instability, he observed a negative relationship between growth and initial level of per capita GDP. The latter multiple regression shows convergence in the usual sense, that is, poorer countries grow faster after controlling for certain variables, specially human capital.

In Table 1 I show the results of some of Barro's more important regressions were the dependent variable is growth 1960-1985, and the independent variables are initial level of per capita GDP (GDP60), secondary and primary enrollment rate in 1960 (SEC60 and PRIM60) and literacy rate in 1960 (LIT60) as proxies of human capital, government consumption over GDP (GOVEXP) and magnitude of the deviation of purchasing power parity value for the investment deflator from the sample mean in 1960 (PPPI60DEV) as measurement of distortions, revolution and military coup (REVCOUP) and number of assassination (ASSASS) as measurement of political instability, and the variables AFRICA and LAT. AMER. are *dummy* variables that take the value one if the country belongs to any of these regions. The coefficients show the expected results, negative relation between growth and distortions and political instability, and positive relation with respect to any of the human capital measurement.

TABLE 1

DEPENDENT VARIABLE IS GR6085

	(1)	(2)	(3)
Const.	0.0302 (.0066)	0.0286 (.0065)	0.0332 (.0067)
GDP60	–0.75 (.0012)	–0.0069 (.0011)	–0.0068 (.0009)
SEC60	(0.0305 (.0079)	0.0385 (.0085)	0.0133 (.0070)
PRIM60	0.025	0.035 –0.0171	0.0263
LIT60		(.0087	
GOVEXP	–0.119 (.028)	–0.118 (.028)	–0.094 (.026)
REVCOUP	–0.0195 (.0063)	–0.0179 (.0062)	–0.0167 (.0062)
ASSASS	–0.0333 (.0.155)	–0.0325 (.0151)	–0.0201 (.0131)
PPI60DEV	–0.0143 (.0053)	–0.0147 (.0054)	–0.014 (.0046)
AFRICA			–0.0114 (.0039)
LATIN AMERICA			–0.0129 (.0030)
R-Squared	0.56	0.57	0.62
N	98	98	98

Mankiw, Romer and Weil (1990), in a very interesting paper, analyze how well Solow's model fits the cross-countries data. From the very first sentence the reader knows what to expect from this paper: "This paper takes Robert Solow seriously". They found that half of the cross country variation in income per capita is explained by the growth rate of population and the savings rate. Though the model predicts the direction of the effects, it does not predict the magnitude correctly. Then they worked with an augmented model that includes human capital and they obtained a more "reasonable" magnitude of the parameters as well as the model counts for about eighty percent of the cross country variation.

They specify a production function similar to the one in the previous section $Y(t) = [K(t)]^{\alpha} [A(t) L(t)]^{1-\alpha}$. The capital stock depreciates at rate δ, the labor force grows at rate n and A grows at rate g. Now small y and k indicates output and capital per effective units of labor, *i. e.*, $y = Y/AL$ and $k = K/AL$. Now the total depreciation of per effective unit of labor will be $(n + g + \delta)$ in equation (2) of the capital accumulation and the steady state per capita capital will be $k = (s/(n + g + \delta))^{1/(1-\alpha)}$. This allows to determine the steady state per capita income (expressed in logarithmic terms to have a linear equation to be estimated):

$$\ln (Y/L) = \ln A(0) + gt + \frac{\alpha}{(1-\alpha)} \ln (s) - \frac{\alpha}{(1-\alpha)} \ln (n + g + \delta) \qquad (4)$$

Equation (4) corresponds to equation (6) in their paper and after they specify $\ln (A(0)) = a + \varepsilon$, and assuming independence between ε and s and $(n + g + \delta)$ they proceed to estimate (4) using this specification. They used the growth rate of labor force and assume that $g + \delta = 0.05$ and s is calculated as the investment rate.

Using Summer and Heston (1988) data set they proceeded to estimate (4) using three different samples: 98 non-oil exporter economies, 75 countries from the previous sample minus all those countries that Summer and Heston have evaluated with letter D in terms of data reliability, and a third sample of the 22 OECD countries. They estimated the model with and without the restrictions that the parameter of s and $(n + g + \delta)$ are of the same magnitude but with opposite signs. The restriction cannot be rejected in any of the three samples at the classical levels of significance. From the estimation the implied α's obtained were 0.6, 0.59 and 0.36 for each sample. This is higher of what Solow's model implies which was an α of approximately 0.3.

Then they decided to work with an augmented model including human capital. Now the specified production function has $Y = K^{\alpha} H^{\beta} (AL)^{1-\alpha-\beta}$, where H represents human capital. They also stated a similar accumulation equation for human capital than for physical capital but making a distinction between the savings rate in human capital and physical capital and assumes the same depreciation rate for both types of capital. Going through the same steps than before they arrive to equation (5) which, in spirit, is very similar to (4).

$$\ln (Y/L) = \ln A(0) + gt - \frac{\alpha}{1-\alpha} \ln (n + g + \delta) + \frac{\alpha}{1-\alpha} \ln (s_k) + \frac{\beta}{1-\alpha} \ln (h^*) \qquad (5)$$

In equation (5) s_K and h^* means the saving rate in physical capital and the level of human capital in steady state.

Again they estimate (5) for the three samples and with and without the constraint on the parameters. Again the constraint cannot be rejected so they calculated the implied α which has 0.31, 0.29 and 0.14, and the implied β which has 0.28, 0.30 and 0.37 for each sample. They concluded that Solow's model does not predict convergence for all countries in the sample but each country converges to its own steady state. There will be convergence after controlling for growth rate of the population and the saving rate that could be called "conditional convergence". According to this study there is no evidence of externality to capital accumulation as Romer (1987) suggested, since the elasticity of output with respect to capital is the same as the capital share and it is about 1/3.[7]

Concerning the discussion about convergence Quah (1990) made an interesting point based on the explanation for Galton's Fallacy. He showed that even if the variance of the growth rate remain unchanged over time the coefficient of the regression of growth rate on initial level of per capita income is negative. Even though there is no convergence, the traditional regression analysis will still show an evidence of convergence.

For the above reason Barro and Sala i Martin (1990) distinguish between what they called σ-convergence and β-convergence. The former comes just from the analysis of the standard deviations of the growth rate across-country or across-regions over time. The latter comes from the estimated β in the regression equation

$$\log (y^i_t / y^i_{t-1}) = \alpha - (1 - e^{-\beta}) [\log (y^i_{t-1}) - g(t-1)] + u^i_t \qquad (6)$$

where $\alpha = g + (1 - e^{-\beta}) \log (y^*)$, g is the exogenous growth rate of technological changes, y is per capita output or income and the * means steady state. Note that β measure the speed of capital to reach the steady state. Specifically if β is positive we will find across-country convergence or what they called β-convergence.

Using (6) it is possible to find the evolution of the variance of growth rate, σ^2 as

$$\sigma^2_t = (e^{-2\beta} \sigma^2_{t-1} + \sigma^2_{ut}) \qquad (7)$$

where σ^2_{ut} is the variance of the disturbance in (6), and it is assumed to be constant for all t, σ^2_u. The solution of (7) is

$$\sigma^2_t = \frac{\sigma^2_u}{1 - e^{-2\beta}} + \left(\sigma^2_0 - \frac{\sigma^2_u}{1 - e^{-2\beta}} \right) e^{-2\beta t} \qquad (8)$$

where σ_0^2 is the variance of the log (y_0). Clearly from (8) the variance could decrease or increase over time depending on whether the initial variance is greater or smaller than the steady state value of σ^2. Therefore, β-convergence is necessary but not sufficient for σ-convergence.

They also analyze the impact of shocks in the regression analysis. Example of these shocks are the oil price or the agricultural product price in the regression across-states of the US.

They use data on personal income and per capita output for the different states of the US. Without including proxies for the shocks they found that β tends to be positive

but unstable in a sense that is quite different for the different sub-period. The restricted non-linear regression (that the beta is the same for all the sub-periods) was run and the null hypothesis of coefficients equality is rejected. After including the shocks, measured as a sectoral composition[8], the null hypothesis that the coefficients are equal cannot be rejected.

The data also shows σ-convergence across the states in personal income and a little bit weaker when data on per capita output is used.

After analyzing the Summer-Heston data set for 98 countries and they found the same that Barro (1989) did, it is necessary to control for some other variables in order to obtain the desired result of convergence.

Cross-country studies have emphasized the role of macroeconomic variables as determinants of growth. This is the case of Fisher (1991) and Kormendi and Meguire (1985). While the former control for the typical variables mentioned above (*i. e., proxy* for human capital, initial real GDP, investment) and some macroeconomic policy variables, the latter concentrates mainly in macroeconomic variables based in the macro literature (*e. g.*, variance of monetary shocks, growth rate of money supply, government expenditure, etc.). An important findings is that both studies conclude that the inflation rate affects growth negatively.

Apart from the inflation rate, Kormendi and Meguire found that the variations of monetary shocks have an important negative effect on growth. Later they added the investment-income ratio to the growth equations finding that it has an important effect. They also analyze whether macro variables operate through affecting investment and they concluded that these variables affect income both directly as well as through the investment rate.

Fisher also found that the share of investment in GDP is one of the most important variable in explaining growth. This is also true when he studies pooled data of time series and cross-section. On the other hand foreign debt seems important only in the pooled sample. Again the *dummy* variables for Latin America and Africa are significantly important at the classical level of significance. He mentioned that there is not a clear way to how macroeconomic variables affect growth and he believes that it may be through reducing the investment rate. Running regressions using investment rate as dependent variable he found that inflation and the surplus of the government budget negatively affect the investment rate.

I want to close this section by analyzing another group of empirical papers which emphasize the role of international trade and distortions. There exist an enormous amount of literature discussing whether outward oriented economies perform better than those that are inward oriented. The first problem that many of these studies face is the definition of orientation. Here, I will not persist neither in the discussion of this concept nor in the review of the extensive literature since this has been done elsewhere[9]. Instead, I will review some recent papers that investigate the relationship between these variables.

Edwards (1991) analyzes, within a simple model of technological transfer across countries, the implication of trade orientation for growth in developing countries. For a developing country the technological change depends on the gap between the stock of knowledge in that country and the world stock of knowledge; also the country stock of knowledge increases due to the increase in the world stock of knowledge. The impact of the increase in the world stock of knowledge on the country's technological change depends on a parameter β that is a function of the level of trade distortions. This parameter measures the ability of the country to absorb inventions generated by the rest

of the world. The final regression equation uses growth of per capita GDP as dependent variable and the investment rate, the initial knowledge gap and a measure of trade distortions. The initial gap is proxied by the initial per capita GDP and by the number of technical and engineers advocated to R&D. The trade distortions used are, global and for the manufacturing sector, measures of intervention and openness constructed by Leamer (1988). The measure of intervention is defined as the difference between the actual and predicted trade, for a certain country, calculated using a Heckscher-Ohlin model.

Using data from 30 developing countries Edwards ran different regressions using the variables mentioned above and found that the model performs somewhat well and all the coefficients have the expected signs. According to him these measures of openness are more adequate; still he analyzes the same regressions using alternative measures of openness and intervention finding, again and again, that trade distortions are harmful for growth.

Roubini and Sala i Martin (1991) arrive to similar conclusions. They used Barro (1989) cross country regression as a benchmark. The sample size changes according to the availability of the trade distortions data. For each sample size they use regression (3) in Table 1 and they add different measure of trade distortions. To me their main findings is that in most of the cases the inclusion of trade distortions drop the value of the coefficient for the Latin American *dummy* and loss of significance at the conventional level. This would suggest that the poor performance of Latin American countries is due to their inward orientation strategy. The same is not true for African countries for which the *dummy* variable still has a measurable effect on growth.

They also present a theoretical model where they show that financial repression affects growth negatively. Based in studies by some other authors, they relate financial repression with negative interest rate, the reserves held by the banking system and the inflation rate[10]. All of these proxies enter in the regression with the expected sign and most of the time they are statistically significant at the conventional levels and do not change the coefficient obtained with Barro's regressions very much. The differences with the previous set of variables is that the Latin America *dummy* remains significant, unless when measures of financial repression and trade distortions are combined in one variable the Latin America *dummy* become non-significant.

This review did not pretend to be exhaustive. I only tried to illustrate how cross country studies have been conducted using some influential empirical papers. A summary of all the studies is presented in the next table. The comments in the next section try to be as general as possible such that could be applied to the above papers as well as many other cross-country studies.

III. Comments on the Econometrics of Cross-Country Studies

Many of the empirical points made in this section will be based on Barro's (1989) paper since the data are readily available and because it has been used as a benchmark by many authors[11]. In this section I will mainly discuss the following issues: whether the theory is correctly being tested or the authors are testing something else, the interpretation of the coefficients in cross-country studies, errors in variables, and robustness.

Paper	Methodology	Sample	Findings
Convergence			
Baumol (1986)	He runs growth rate between 1870-1985 on initial GDP level.	16 industrialized countries.	He finds convergence in an absolute sense.
De Long (1988)	He corrects Baumol's piece of work by sample selection bias and measurement error in the independent variable.	Same as Baumol's sample minus Japan plus Argentina, Chile, Spain, Portugal, East Germany, Ireland and New Zealand.	There is no convergence if countries that were likely to converge back in 1870 are included and if small measurement error on 1870 GDP are allowed.
Barro (1989)	He runs growth between 1960-1985 on 1960 GDP and other variables to control for initial human capital distortions, *dummy* regions and political instability.	98 countries using Summer-Heston data.	No convergence in absolute terms (growth rate on initial level of GDP), but there exists convergence controlling for the variables mentioned in column 2.
Mankiw-Romer-Weil (1992)	They run log of labor productivity on saving rate, growth rate of population, depreciation rate plus the exogenous growth rate of the technology level. Later they include a *proxy* of human capital.	98 Non-oil exporter, 75 countries with intermediate quality of data, 22 OECD countries. All samples come from Summer-Heston data.	There are no substantial externalities associated to physical capital accumulation. There is convergence in level of GDP per working person. The value of the capital share (α) is too large using the textbook Solow's model. But using an augmented Solow model, that includes human capital, the α reaches the expected 1/3.
Barro and Sala-i-Martin (1990)	They distinguish between σ-convergence (the standard deviation of per capita income) and β-convergence (from the regression of growth rate on the initial level).	48 states of USA. They calculate growth rate for different time periods since 1880 to 1988.	They found β-convergence using per-capita personal income and per-capita gross state product. The estimated β tends to be more stable after controlling by region and by sectoral composition. The speed of convergence is slower than the one predicted by traditional textbook models.

Macroeconomic Variables and Growth			
Kormendi and Meguire (1985)	The macroeconomic variables included are the standard deviation of money supply shocks, the mean of money supply growth, the rate of inflation, growth of exports as proportion of output, ratio of government spending to output.	47 countries.	They found evidence that growth depends on the standard deviation of money supply shock and investment rate. Weak or no evidence that openness, government spending and inflation rate affect growth.
Fisher (1991)	He runs regressions of growth rate on initial GDP, initial school enrollment, investment share, inflation, external debt, dummies for region and government budget surplus.	Pooled cross-section time series data for the period 1972-85.	He found some weak relations between the macroeconomic variables included an growth. An indirect effect through investment seems to be the most important one.
Openness and Growth			
Edwards (1991)	Technological change depends on the gap between the country's stock of knowledge, and the ability to absorb new technology. The latter if associated to the degree of openness.	Sample of 30 developing countries.	He found a robust relationship between growh in per-capita GDP and different measures of openness. The gap between the stocks of knowledge was estimated by initial GDP and by R&D. He also includes investment to GDP ratio which showed a strong positive relation with growth.
Roubini and Sala-i-Martin (1991)	The same context as in Barro (1989)'s study. They add a measure of effective rate of protection, exchange rate misalignment, and financial repression.	Sample of 85 countries and 53 countries depending on the availability of the data.	Negative relation between trade distortions, financial repression and growth. Financial repression was proxied by real interest rate, bank's reserves to money, and inflation rate. A *dummy* for Latin America in Barro (1989) becomes non significant when financial repression and trade distortions are included.

Is the theory being tested?

As shown in the previous section there has been an increased amount of literature testing the convergence hypothesis. Maybe one of the closets attempts to test what Solow's model really predict was made by Mankiw *et al.* (1990). They basically derived the structural regression equation directly from the model. When they run the regression they carefully controlled for the variables that affect the steady state across-country. The main conclusion was that countries converge to a certain level of income per capita, given the saving rate and the growth rate of population, which is one of the implications of the theoretical model.

Many of the papers revised do not seem to be able to derive a regression equation directly from the models to be tested. Moreover, many of the studies introduce secondary and primary enrollment as a measure of initial human capital. This variable can take different interpretation. Take as an example the results from Barro (1989) presented in Table 1. The initial GDP is used as a *proxy* of the initial stock of capital, then countries with low per capita capital are farther from the steady state and therefore grow faster. To me, the same interpretation could be derived for initial secondary and primary enrollment rates, if we broaden the concept of capital to include human capital. If this is the correct interpretation then the coefficient of these variables would have the "wrong" sign in Table 1. If the interpretation is that the initial level of human capital summarizes the ability of the country to absorb future technological progress then the coefficients have the "right" signs. But it is certainly hard to argue that initial human capital is a variable necessary to control for steady state. In that respect the average enrollment as used by Mankiw *et al.* (1990) seems to be a more suitable variable for this purpose. The first interpretation above, for the inclusion of initial level of human capital, could be the reason why the literacy rate in 1960 shows a negative sign in the second regression in Table 1.

It is hard to think that Barro's regressions are a test of the neoclassical growth theory against some alternatives hypothesis. But I think Barro's study is extremely useful, because it shows the correlations between growth rate and different variables that have been presented in the literature.

This final point about hypothesis testing come from Leamer (1978, 1989). Most of these studies are testing, I believe, the null hypothesis of convergence against the alternative of non-convergence. But we cannot interpret the no rejection of the null hypothesis as a clear evidence of the neoclassical model of growth. Because there are so many variables included in each regression that is really hard to figure out whether the analysis corresponds to a test of one model against another. As Leamer has pointed out, most of empirical studies lack of a clear alternative hypothesis[12].

It is clear by now is that convergence cannot be seen as a phenomenon implying that all the countries, in the long run, will have the same income per capita, since groups of countries, with similarities in certain variables, will converge to the same per capita income. A group that converge is what Baumol called the convergence club, but what is really happening is that there exist many of these clubs as we will see in the next section. For this reason when the hypothesis is tested it is necessary to be carefull not to bias the sample against or in favor of what is being tested[13]. For these reasons models with more than one long run equilibrium seems to be more useful to understand the data.

To study convergence most of the research have been conducted using per capita income or per capita GDP instead of labor productivity as dependent variable. For theoretical reasons what really matters for convergence is labor productivity. The substitution of labor productivity by per capita income introduces a measurement error problem as noticed by Wolff (1991). This is one piece of evidence against the assumption that the theory is being correctly tested.

Also some of the models work with labor measure as effective unit. Take for example Mankiw *et al.* work. They worked with the neoclassical growth model, expressing labor as effective units. In the regression they just use raw figures of labor force in the regression, since they make an assumption about the growth rate that allows them to work with detrended variables. Also the interpretation of effective labor unit is frequently associated (as in Lucas, 1988) with human capital, but later in their paper they include human capital as an argument of the production function. It may be that, if they had used labor corrected by human capital as a measure of effective labor units in the first regression, the second part of the model or the augmented model will not be necessary. It seems that the distinction between human capital and effective units of labor does not exist. In other words, they are controlling twice for the same variable.

About the interpretations of the coefficients in cross-country studies

When studying the growth phenomenon, one has to be careful with the interpretation of the coefficients in a cross-country study. In a cross section regression, like those presented in Table 1, there is the implicit assumption that a poor country will successively behave as a low-middle income country, as a high-middle income country, and as a high income country in the growth process. It is really hard to believe than an African country will behave, for example, like Colombia, later like Korea, and later like Switzerland as the process of growth goes on. This implicit assumption makes me interpret the results of cross country very careful. In the same spirit is the point made by Bernard (1990) who developed and tested the concept of stochastic convergence. His point is related with the idea that the same technology is not available for all the countries simultaneously, specially for the post war period. Given that neoclassical theory does not predict that countries with different microeconomic parameters will converge and the time periods is not long enough he would expect rejection of the convergence hypothesis.

Also it is hard to believe that the parameters are the same for all the observations. For example, it is not different to run a regression of consumption on income for the habitants of specific city where the population is relatively homogenous, than a cross country regression.

The question then is obvious: how can I capture this effect? I have two possible answers. One it is neglect cross country study and just analyze country case study. I am aware that this is not a good answer since there are some important and useful correlations that could be picked across country that could not be analyzed with a case study. The second answer is reformulate the regression models. For example, suppose that I am interested in the effects of a set of variables, X on Y after controlling for a set of variables, Z_1. But X could be also explained by another set of variables, Z_2, such that what I will end up estimating is an indirect effect of Z_2 on Y. Moreover assume that the coefficients also depend on a set of variables τ, where τ can include from X, Z_1 and Z_2. Therefore the explicit model to be estimated would be:

$$Y = X_1\beta_1 + Z_1\beta_2 + \mu$$
$$X_1 = Z_2\gamma + \varepsilon \qquad (9)$$
$$\beta = \tau\alpha + e$$

The above system will introduce non-linearities and interactions between variables[14]. A very simple example is the regression of growth rate on initial per capita GDP. It is well known that as a result of this regression a coefficient equal to zero is obtained. Using the sample of 98 countries that Barro used I computed the regressions presented in Table 2. If we allowed for the interaction between the Africa *dummy* and Latin America *dummy* there immediately appears to be evidence of convergence. The coefficient of GDP remains equal to zero. The third regression also includes the interaction between a *dummy* for OECD countries and initial GDP. As expected the coefficient is negative but now the coefficient on GDP60 is highly positive.

The explanation for this results is very simple. The *dummy* variables are controlling for similarities across a group of certain countries and they are therefore controlling for steady state. The coefficient of GDP60 in the first regression depends on economic variables that affect the steady state according to the theoretical models as well as a group of other variables that is hard to control for. The coefficient on GDP60 in the third regression is positive because countries not included in the three groups cannot be assumed to converge by any means.

This very little sensitivity analysis, in the sense that I assumed that the coefficient depends on the "arbitrary" set of countries, is just an example to point out that it is necessary to explore the cross section results in light of the equations set (9).

TABLE 2

DEPENDENT VARIABLE IS GR6085

	(1)	(2)	(3)
Const.	0.02	0.026	0.021
	(.003)	(.003)	(.003)
GDP60	0.001	0.001	0.011
	(.001)	(.001)	(.004)
AFRGDP60		-0.015	-0.02
		(.005)	(.005)
LATGDP60		-0.006	-0.015
		(0.002)	(.003)
OECGDP60			-0.01
			(.003)
R-Squared	0.01	0.17	0.24
N	98	98	98

Measurement error problem

Despite the fact that many authors have mentioned this problem, very few tackle the issue in a formal way. Wolf (1991) showed how measurement error in the dependent variable and also in human capital biased the parameters against the convergence hypothesis. The former was mentioned earlier, the theory predicts convergence in labor productivity and not in per capita income. There are two consequences of using per capita income instead of labor productivity: the former underestimates the initial level for poorer countries relatively to richer countries and also underestimates their growth rate. Both effects work against convergence since they biased the coefficient of growth on initial values to zero or positive relation.

The second source of bias is related to a miss measurement of human capital. If instead of working with effective units of labor, or labor corrected by human capital, the researcher works with just raw labor, again the initial productivity will be underestimated for poorer countries relatively to richer countries but now their growth rate will be overestimated. The first effect as in the previous case biases the coefficient toward zero the second biases it to the opposite direction. So the final effect is ambiguous.

After taking care of this problems by including the "correct" variables in the regression plus some others, like savings and the number of revolutions and coups, that control for steady state he found evidence of convergence.

Leamer (1991a, 1991b) makes a useful analysis of how serious the errors in variable problem is in a cross country study of growth. Using equation 1 in Table 1 from Barro's data set he analyzes the importance of errors in variables assuming that all observations are measured with error. Also splitting the sample in two under the assumption that the parameters from the developing countries sample may be different than those from the sample of the developed countries.

Leamer (1991a) uses the framework developed in Klepper and Leamer (1984) and Leamer (1983b). In the first paper they showed that if the coefficients from the direct and all reverse regression lie in the same orthant then the set of possible values of the coefficients is bounded. If this is not so (what actually happens in the analysis of growth equation) then the set of possible values of each coefficient is the real line, and therefore additional information about the magnitude of measurement error is necessary. The reverse regression computed show that there is a problem to estimate the bounds for the coefficients treating the data as coming from one sample or from two samples. The results show that if the researcher is able to assume that the PRIM60 and REVCOUP are measured accurately then the worst consequence of errors in variables problem will not persist[15]. His analysis also shows that, in most of the cases, if the noisy variance is more than half of the total variance of the variable then the set of estimates is unbounded.

The techniques developed in Leamer (1991b) paper are very useful not only to analyze the problem of erros in all variables but also when one wants to analyze two noisy data set. Here, Leamer proposes a bayesian methodology where the pooled estimates from developing and developed sample depends on three parameter: the lack of confidence in the prior, the experimetal contamination of the data and the degree of similarities between the two samples. With not doubt the analysis of experimental contamination parameter is one of the important methodological contribution of that paper. This parameter measures the importance of the contamination bias. In the regression model the explanatory variable appears twice, once to represent the "true"

effect and the second, to represent the experimental bias. The experimental bias parameter measure the variance of the second parameter mentioned above. He conducted a sensitivity analysis but the results do not change very much since the parameters from each sample are relatively close. The one that seems to have a very different effect in each sample is government expenditure which is larger (in absolute value) for the case of the developing countries than for the developed countries.

This literature implies that the errors in variable problem is not trivial and needs to be analyzed more carefully, since the conclusions are very sensible to the assumption of "clean" data. In the case of growth studies this is specially true, since all the papers reviewed in the previous section used proxies for initial stock of capital, human capital and so on, and moreover it is hard to believe that the aggregate data is measured completely accurate.

Robustness

Using the methodology introduced in Leamer (1983a), and Leamer and Leonard (1983), Levine and Renelt (1990) analyze the robustness of the cross-country growth regressions. In their interesting work they compute the bounds for the coefficients of interest using a sensitivity analysis given by the imposition of different constraints in the parameters of doubtful variables. Specifically, the constraints consist in different sets of combinations of doubtful variables.

The idea is to look at the signs and size of the coefficients when then researcher change a little bit the assumption of the model which is reflected in the regression equation. An estimate will be robust if the minimum and maximum coefficients have the same sign. Levine and Renelt take many of the regressions estimated in the growth literature and see how the coefficients change under a small change on the right hand side variables.

It is true that many indicators of macroeconomic policies, for example monetary policy as shown in Kormendi and Meguire (1985), are correlated with growth but taken them individually or as a group they are fragile. In other words the correlation depends in an important way of what variables are held constant.

Total investment has a robust positive correlation with growth but the same is not true for government investment. Their interpretation is that private investment has a higher return compared to public investment. In general there is no robust relation between fiscal policy in cross country regression.

About trade and price distortions, they found robust correlation between the share of trade on GDP with the investment rate. After controlling for the investment rate in the growth equation, they could not find any robust relation between trade or international trade distortions and growth.

In summary, even though almost all the results in cross country studies show, intuitively, reasonable correlations between a set of macroeconomics variables and growth, almost all of them seem not to be robust[16]. This discussion about robustness makes me return to my previous point about the interpretation of the cross country coefficient. These are average coefficients showing some average correlation. The fact that almost every particular variable included in these regressions seem fragile is to be taken as an additional incentive to proceed with country case studies using more disaggregate data. From that literature there is evidence that many of these variables affect the performance of countries, but many time the analysis is based in the

composition of the aggregate variable rather than the level. The level is what have been used in cross-country studies[17].

Measurement of human capital

By now there is no doubt that human capital plays a key role in explaining growth from both, a theoretical and an empirical point of view. The goal of this section is to make the researcher aware of the problems that can be found in estimating this variable.

The first concept that comes to mind when we hear human capital is education. There is no doubt that these two variables are related. However, education acquired through schooling is not the only way to invest in human capital. Experience, on-the-job training and improvements in health are also ways to accumulate human capital. Because schooling is easier to compute, researchers usually have used this as a *proxy* of human capital. Here we have a source of measurement error in this variable that should be taking into account in the regressions.

As we saw in the previous section many authors have used secondary and/or primary enrollment to control for human capital. The main reason for doing this is the readily availability of the data. There is no doubt that secondary and primary enrollment will affect the level of education in four or eight more years, but it is more accurate to calculate the human capital embodied in the labor force which is the part that actually enters in the production function. An effort in this direction was made by Wolf (1991). He calculated the number of years of schooling of the population above primary school age and not in school, as a *proxy* of effective units of labor.

Moreover, what we would like to see is an estimation of a composite commodity like in the case of physical capital that could be valuated in constant currency. Efforts in this direction for particular countries have been done by Haindl and Fuentes (1986), Harberger and Selowsky (1969), and Selowsky (1969).

Specifically, Selowsky (1969) called the attention on the concepts of education deepening and education widening. The former is related to the increase in the level of education of the labor force, while the latter is the effect of the increase in the labor force with the average level of education. In other words education also contribute to growth in maintaining constant the human capital of the increases in labor force. Assuming different elasticy of substitution across different skills he concludes that the second concept is much more important in developing countries like Chile and Mexico than in USA. The literature that deals only with changes in relative distribution of skill will underestimate the contribution of education to economic growth by the second of the above concepts.

In summary, the human capital variable is something much more complicated to measure than just enrollment rate in primary and secondary school. We want a variable that it is included in the production function like the average schooling of the labor force or, even better, a composite commodity called human capital where each level of education is weighted by a *proxy* of its marginal productivity. Other proxies that come to my mind are for example number of graduates from the third level of education than can be obtained from UNESCO Statistical Yearbook, number of scientists and engineers engage in R&D from the same source (already used by Edwards (1991) as measure of the initial gap in knowledge), or a simple categorization of the skill levels like the one used in Leamer (1984)[18]. In his categories he divides labor as those workers classified as professional or technical by the ILO (variable called labor 1 in his book), number or literate non-professional workers (labor 2) and illiterate workers (labor 3).

V. Concluding Remarks

Cross-country studies have proved to be useful to understand some correlations between aggregate variables (like proxies of human capital, political instability, distortions) and growth. The main problem remains in the interpretation of the coefficient since nobody would expect that the coefficients are the same for all countries. At least they will be different within certain groups of countries.

Despite of many variables that have been entered in the regression models with the sign dictated by the model or the intuition, they do not seem to be robust when the researcher is allowed to change the set of variables called "doubtful". Also, though mentioned in many studies, the problem of measurement error seems to be an important one in cross-country studies of growth.

In summary, cross-country studies seem to be sensitive to the choice of variables (robustness), analysis of errors in variables, and constant coefficient assumption across observation.

Further research should be concentrated in providing a better measure of human capital that is, with no doubt, a very important variable to explain growth. It seems to me that cross-country studies reached a point a strong diminishing returns. Therefore, a direction for further research should take is the country case type of study. In my personal opinion there is already an important number of cross-country studies with relatively similar structures, that now it is necessary to go deeper and see how the different variables discussed in the literature affect a determined country. This conclusion comes from the argument of differences in the cross-country regression coefficients.

Notes

1 For a bit more detailed discussion of the theoretical part see Fuentes (1992), chapter 1.

2 This line was first followed by Uzawa (1965) and later by Lucas (1988). However, the pionner ideas come from Schultz (1961).

3 For an example of this type of modeling see Romer (1986, 1987). For the importance of these non-convexities see Romer (1990).

4 Examples of this type of models are found in Jones and Manuelli (1990), Rebelo (1991) and Fuentes (1992).

5 For further discussion see Jones and Manuelli (1990).

6 Also his (1957) paper originate a hugh literature in what is called the study of TFP or "Solow's residual". Here I am not pursuing to analyze this literature, I would rather concentrate in the cross-country analysis.

7 Also Benhabib and Jovanovic showed that there is no support for thinking in the existence of capital-related externalities. They assume stochastic process for technological shocks than are the same for all countries but each country faces different initial condition. The data seem to support this assumption together with constant return to scale production function.

8 This variable is constructed in a way that if a region has a high component of its output from the agriculture then during periods when the income from agriculture grows particular low this shock will be particular low.

9 For a discussion of the possible definitions of this concept and for an excellent review of this empirical literature see Edwards (1989).

10 Note that the economic interpretation of the inflation rate in the regression equation is different than in the macroeconomic studies by Kormendi and Meguire (1985), and Fisher (1991).

11 As noticed in the previous section many authors used some of the variable in Barro (1989) to develop their empirical tests. For example see Roubini and Sala i Martin (1991), Fisher (1991).

12 Sometimes even a clear null hypothesis is hard to find in empirical studies.

13 This is the point made by Baumol and Wolff (1988) to answer the problem of selection biased pointed out by De Long (1988).

14 For a more complete discussion see Leamer (1989).

15 Even though primary enrollment is well measured, there is still a question if this variable is or not a good *proxy* for human capital.

16 There are several interesting tables presented in the paper that I will not reproduce here, because will not make clearer the discussion. However, I will strongly encourage any interested reader to look at the original paper.

17 For example, analysis of the composition of government expenditures or the structure of taxation could be important in growth. If the government investment substitute private investment instead of complement, one will expect complete different results of the relation between public investment and growth. The same is true for human capital. For a poor country that does not have resources, it will be hard to recommended to invest in R&D if it does not have an adequate level of education for example. Once again cross country show some useful correlation but, to me, it is hard to believe that they are complete test of the theory.

18 See also Fuentes (1992).

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APERTURA Y EFICIENCIA PRODUCTIVA: LA INDUSTRIA CHILENA, 1975-1988*

RAFAEL AGACINO**
Programa de Economía del Trabajo (PET)

GONZALO RIVAS
Programa de Economía del Trabajo (PET)

ENRIQUE ROMAN
Programa de Economía del Trabajo (PET)

Abstract:

The results of Chile's profound economic liberalizations remain the subject of ongoing debate. Using the Total Factor Productivity approach (TFP), we review the industrial sector performance during the 1975-1988 period. Our analysis shows that greater competitiveness dictated by economic liberalization was not accomplished through technical change but, rather, through intensive factor use (1976-81), or extensive factor use (1984-88). After exhaustion of the "easy phase", new levels of productive efficiency necessitated technical innovation, that is, investment in equipment, training, and reorganization of productive processes. However, after the 1982-83 crisis, firms did not follow this path: previous financial stress and low wage costs determined a growth path based on extensive use of labor, thereby delaying technological modernization of the industrial sector.

Introducción

Las economías latinoamericanas se encuentran embarcadas actualmente en un proceso de creciente apertura y liberalización de sus mercados. Ante las deficiencias y problemas de la estrategia de sustitución de importaciones, y a la luz de la evidencia sobre el mayor crecimiento exhibido por los países abiertos a la economía internacio-

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